IS 13340 (1993): Power Capacitors of Self-healing Type for AC Power Systems having Rated Voltage up to 650 V [ETD 29: Power Capacitors]

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भारतीय मानक

ए सी विद्युत तंत्रों के लिए स्वत: ठीक होने वाले 650 वोल्ट की रेटित वोल्टता के संट संधारित्र – विशिष्टि

Indian Standard

POWER CAPACITORS OF SELF-HEALING TYPE FOR AC POWER SYSTEMS HAVING RATED VOLTAGE UP TO 650 V — SPECIFICATION

UDC 621·319·4·027·465

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August 1993 **Price Group 9**

Power Capacitors Sectional Committee, ET 29

CONTENTS

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft fianlized by the Power Capacitors Sectional Committee had been approved by the Electrotechnical Division Council

(*Continued on third cover*)

AMENDMENT NO. 1 MARCH 2002
TO
IS 13340 : 1993 POWER CAPACITORS OF SELF-HEALING TYPE FOR AC POWER SYSTEMS HAVING RATED VOLTAGE UPTO 650 V — SPECIFICATION

(*Page* 6, *clause* **12.2.2**) — Delete h) and j)

(*Page* 7, *clause* **12.3.2**) — Add the following new clause after **12.3.2**.

'**12.4 Special Tests**

These tests shall be carried out by the manufacturer The following shall constitute special tests

a) Ageing test (*see* **26**), and

b) Destruction test (*see* **27**).

(ET 29)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 2 JUNE 2002
TO
IS 13340 : 1993 POWER CAPACITORS OF SELF-HEALING TYPE FOR AC POWER SYSTEMS HAVING RATED VOLTAGE UP TO 650 V — SPECIFICATION

(*First cover page and page* 1, *title*) — Substitute '**1 000 V**' *for* '**650 V**'.

(*Page* 1, *clause* **1.1**, *line* 4) — Substitute '1 000 V' *for* '650 V' .

(*Third cover page, Foreword, lines* 9, 11, 12 *and* 15) — Substitute '1 000 V' *for* '650 V' and wherever occurs in the text.

(ET 29)

Reprography Unit, BIS, New Delhi, India

Indian Standard

POWER CAPACITORS OF SELF-HEALING TYPE FOR AC POWER SYSTEMS HAVING RATED VOLTAGE UP TO 650 V — SPECIFICATION

1 SCOPE

1.1 This standard applies to self healing capacitor units and banks intended to be used, in particular, for power factor correction of ac power systems of upto and including 650 V rated voltage and frequency 15 to 60 Hz

NOTE — *Additional requirements for capacitors* protected by internal fuses as well as requirements for the internal fuses are given in IS 12672 : 1989

1.2 The following are excluded from the scope of this standard

a) Shunt capacitors of non-self healing type for ac power systems having rated voltage of up to 650 V,

b) Shunt capacitors for ac power systems having a rated voltage above 650 V, (under preparation)

c) Capacitors for induction heat-generating plants, operating at frequencies between 40 and 24 000 Hz,

d) Series capacitors (IS 9835 : 1981),

e) Capacitors for motor applications and the like (IS 1709 : 1984 and IS 2993 : 1975),

f) Coupling capacitors and capacitor dividers (IS 9348 : 1979),

g) Capacitors to be used in power electronic circuits (IS 13648 : 1993),

h) Small ac capacitors to be used for fluorescent and discharge lamps (IS 1569 : 1976),

j) Capacitors for suppression of radio interference (IS 3723),

k) Capacitors intended to be used in various types of electrical equipment and thus considered as components,

m) Capacitors intended for use with dc voltage superimposed on ac voltage

1.3 Accessories such as insulators, switches, instrument transformers, fuses, etc, shall be in accordance with the relevant Indian Standards

2 REFERENCES

The Indian standards listed in Annex A are necessary adjuncts to this standard

3 TERMINOLOGY

3.0 The following definitions in addition to those given in *IS 1885* (*Part 42*) : 1986 shall apply

3.1 Capacitor Unit

An assembly of one or more capacitor elements in the same container with terminals brought out

3.2 Capacitor Bank

A number of capacitor units (two or more) connected electrically so as to act together A three-phase bank may be composed of three single-phase capacitor units

3.3 Self-Healing Capacitor

A capacitor, the electrical properties of which, after local breakdown of the dielectric, are rapidly and essentially restored

3.4 Rated Capacitance of a Capacitor (C_N)

The capacitance value for which the capacitor has been designed

3.5 Rated Output of a Capacitor (Q_N)

The reactive power derived from the rated values of capacitance, frequency and voltage (or current)

3.6 Rated Voltage of a Capacitor (U_N)

The rms value of the alternating voltage for which the capacitor has been designed

NOTE — In the case of capacitors consisting of one or more separate circuits (for example, single phase units intended for use in polyphase connection or polyphase units with separate circuit) U_N refers to the rated voltage of each circuit For polyphase capacitors with *internal electrical connections* between the phases and for polyphase capacitor banks, U_N refers to the phase to phase voltage

3.7 Rated Frequency of a Capacitor (F_N)

The frequency for which the capacitor has been designed

3.8 Rated Current of a Capacitor (I_N)

The rms value of the alternating current for which the capacitor has been designed

3.9 Voltage Factor (V_f)

The ratio of maximum permissible voltage level to the rated voltage of the capacitor

4 SERVICE CONDITIONS

4.1 Normal Service Conditions

This standard prescribes requirements for capacitors intended for use in the following conditions

a) *Residual Voltage at Energization* — Not to exceed 10 percent rated voltage (*see* clause **7.1** **D-5** and **B-3**)

b) *Altitude* — Not exceeding 1 000 m

c) *Ambient/Air Temperature Categories* — Capacitors are classified in temperature categories, each category being specified by a number followed by a letter. The number represents the lowest ambient/air temperature at which the capacitor may operate. The letters represent upper limits of temperature variation ranges, having maximum values specified in Table 1. The temperature categories cover the temperature range of −10° to +55 C

4.1.1 The lowest ambient air temperature at which the capacitor may be operated should be −10 C

For indoor use, a lower limit of −5°C is normally applicable

Table 1 is based on service conditions in which the capacitor does not influence the ambient air temperature (for example, outdoor installations)

4.1.2 If the capacitor influences the air temperature, the ventilation and/or choice of capacitor shall be such that the Table 1 limits are maintained. The cooling air temperature in such an installation shall not exceed the temperature limits of Table 1 by more than 5°C

Any combination of minimum and maximum values can be chosen for the standard temperature category of a capacitor, for example, −10/A or −5/D.

Preferred standard temperature categories are −10/A and −5/C

4.2 Unusual Service Conditions

Unless otherwise agreed between the manufacturer and the purchaser, this standard does not apply to capacitors, the service conditions of which, in general, are incompatible with the requirements of the present standard

5 RATINGS

5.1 Rated Outputs

The preferred rated outputs of capacitor unit in kVar at a frequency at 50 Hz shall be 1, 2, 3, 4, 5 10, 12 5, 15, 20, 25, 30 40 and 50

NOTE — Preferred rated output for capacitor bank should be in combinations of unit size chosen

5.2 Preferred Rated Voltage

The preferred rated voltage of the unit or bank shall be 240 V for single phase and 415 or 440 V for three-phase systems (*see* IS 12360 1985).

Table 1 Categories of Ambient Temperatures

(*Clauses* 4 1, 4.1 1 *and* 4 1 2)

Symbol	Maximum	Ambient Air Temperature (°C) Highest Mean Over any Period of	
		24 hours	1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

NOTES

1 The temperature values according to Table 1 may be found in the meteorological temperature tables covering the installation site

2 Higher temperature values than those indicated in Table 1 may be considered in special applications by mutual agreement between manufacturer and purchaser. In this case, the temperature category shall be indicated by the combination of minimum and maximum temperature values, for example −10/60

5.3 Rated Frequency

The standard frequency for the purpose of this standard shall be 50 Hz.

NOTE — If a frequency higher or lower than that stated above is specified by the purchaser, it does preclude compliance with this standard. In such a case corresponding changes, where necessary, shall be taken into account as indicated in their relevant places.

6 OVERLOADS

6.1 Maximum Permissible Voltages

6.1.1 *Long Duration Voltages*

Capacitor units shall be suitable for operation at voltage levels according to Table 2 (*see* **D-2** and **D-5**).

The amplitude of the overvoltages that may be tolerated without significant deterioration of the capacitor depends on their duration, the number of applications, and the capacitor temperature (*see* **D-2**). It is assumed that the overvoltages given in Table 2 and having a value higher than $1 \cdot 15 \times U_N$ occur 200 times in the life of the capacitor.

6.1.2 *Switching Voltage*

The switching of a capacitor bank should be carried out by a restrike free circuit breaker so that the first peak of transient overvoltage does not exceed $2\sqrt{2}$ times the applied voltage (rms value) for a maximum duration of 1/2 cycle.

6.1.2.1 Five thousand switching operations per year are acceptable under these conditions taking into account the fact that some of them may take place when the internal temperature of the capacitor is less than 0 C but within the temperature category. [The corresponding transient overcurrent may at a peak reach 100 times the value I_N (*see* **D-6**)]

In the case of capacitors that are switched more frequently, the values of the overvoltage amplitude and duration and the transient overcurrent shall be limited to lower levels with the use of current limiting devices (*see* **D-7**). These limitations and/or reductions shall be agreed upon between the manufacturer and the user.

6.2 Maximum Permissible Current

Capacitor units shall be suitable for continuous operation at an rms current of 1·30 times the current that occurs at rated sinusoidal voltage and rated frequency, excluding transients. Taking into account the capacitance tolerances of $1 \cdot 1\ C_N$, the maximum permissible current can be up to $1 \cdot 43\ I_N$.

These overcurrent factors are intended to take care of the combined effects of harmonics (*see* Annex B) and overvoltages up to and including $1.10\ U_N$, according to **6.1.1**.

Table 2 Permissible Overloads

(*Clause* 6.1.1)

Operating Frequency	Voltage Factor (Vf)	Maximum Duration	Observation
Power frequency	1·00	Continuous	Highest average value during any period of capacitor energization. For energization periods less than 24 h, exceptions apply as indicated below (*see* D-2)
Power frequency	1·10	12 h in every 24 h	System voltage regulation and fluctuations
Power frequency	1·15	30 min in every 24 h	System voltage regulation and fluctuations
Power frequency	1·20	5 min	Voltage rise at light load (*see* **D-2**)
Power frequency	1·30	1 min	
Power frequency plus harmonics	Such that the current does not exceed the value given in **6.2.1** (*see* also **D-6** and **D-7**)		

7 SAFETY REQUIREMENTS

7.1 Discharge Device

Each capacitor unit or bank shall be provided with a directly connected discharge device. The discharge device shall reduce the residual voltage from the crest value of the rated value U_N to 50 V or less within 1 min, after the capacitor is disconnected from the source of supply

There must be no switch, fuse or any other isolating device between the capacitor unit and the discharge device.

A discharge device is not a substitute for short-circuiting the capacitor terminals together and to earth before handling

NOTES

1 Capacitors connected directly to other electrical equipment providing a discharge path shall be considered properly discharged, provided that the circuit characteristics are such as to ensure the discharge of the capacitor within the times specified above

2 Discharge circuits must have adequate current-carrying capacity to discharge the capacitor from the peak of the 1 3 U_N over voltage according to **6.1.1**

3 A formula for the calculation of the discharge resistance is given in **B-4.3**

4 Since the residual voltage at energization must not exceed 10 percent of the rated voltage [*see* **4 1** (i)] discharge resistors with lower resistance or additional switched discharge device may be needed, if the capacitors are automatically controlled

5 A residual charge may sometimes be left on the interconnections of series connected capacitors due to blown fuses, interrupted internal connections, or non linear behaviour of the dielectric resulting from over stressing These interconnections, therefore, shall be short circuited to earth before handling

7.2 Container Connections

To enable the potential of the metal container of the capacitor to be fixed, and to enable carry the fault current in the event of a breakdown to the container, the container shall be provided with a connection capable of carrying the fault current

7.2.1 *Earth Connection*

If the metal container of a capacitor is at earth potential in normal service, it shall be possible to connect it to earth in a reliable way, and clearly marked with the symbol ⏚ .

7.3 Other Safety Requirements

Capacitors shall comply with the relevant general safety regulations for power installations, that is, Indian Electricity Rules, 1956.

8 GUIDE FOR INSTALLATION AND OPERATION OF POWER CAPACITORS

8.1 A general guidance for proper installation and operation of shunt capacitors is given in Annex D.

9 INFORMATION TO BE GIVEN WITH ENQUIRY OR ORDER

The particulars required in Annex E shall be provided by the purchaser if required by the manufacturer.

10 MARKING

10.1 Rating Plate of the Unit

The following information shall be marked indelibly, either directly or by means of a plate, on each capacitor unit.

a) Reference to this Indian Standard (for example IS ..),

b) Identity of the source of manufacture,

c) Identification number and year of manufacture The year may be a part of the identification number or in code form;

d) Rated output, Q_N in kilovars,
For three-phase units the total output shall be given (*see* Annex B),

e) Rated voltage U_N, in volts or kilovolts;

f) Rated frequency f_N, in Hertz;

g) Temperature category,

h) Discharge device shall be indicated by wording or by the symbol —▭— or by the rated resistance in kilo-ohms or megohms; the symbols I or E shall be used for internal or external discharge device and IC for inductive coil when provided in the capacitor,

j) Reference to self healing design, SH or/ ⧺ and type of dielectric MPP/MP (*see* Note 4);

k) *Connection Symbol* - All capacitors, except single-phase units having one capacitance only shall have their connection indicated For standardized connection symbols (*see* **10.2**);

m) Internal fuses, if included, shall be indicated by wording or by the symbol;

n) Insulation level U_i in kV (Only for units having all terminals insulated from the container.),

The insulation level shall be marked by means of two numbers separated by a stroke, the first number giving the rms value of the power frequency test voltage in kilovolts, and the second number giving the crest value of the lightning impulse test voltage, in kilovolts (for example, 3/15 kV).

For units having one terminal permanently connected to the container and units for non-exposed installation and not tested according to **24**, this information should be 3/-.

p) Symbol for the overpressure disconnector, ⏆, if provided in the capacitor.

NOTES

1 For small units where it is impracticable to indicate all the above items on the rating plate, items (k), (n) and (j) may be stated in an instruction sheet. The rating plate shall bear a reference to this sheet.

2 Further information which is of importance for the safety of persons or equipment shall be stated either on the rating plate or in an instruction sheet. In the latter case the rating shall bear a reference to this instruction sheet.

3 A warning instruction that 'DISCHARGE CAPACITORS BEFORE HANDLING' should be prominently marked in red.

4 The notations used for dielectric are MPP = Metallized polypropylene, and MP = Metallized paper.

10.2 *Standardized Connection Symbols*

The type of connection shall be indicated either by letters or by symbols given below.

D or Δ = delta

Y or Y = star

YN or Y̶ = star, neutral brought out

III or III = three sections without interconnections

10.3 Marking of the Bank

The following minimum information shall be given by the manufacturer in an instruction sheet, or alternatively, on request of the purchaser, on a rating plate:

a) Reference to this standard that is IS 13340 : 1993,

b) Identity of the source of manufacture;

c) Rated output Q_N, in kilovars (total output to be given);

d) Rated voltage U_N, in volts;

e) Connection symbol; for standardized connection symbols (*see* **10.2**). The connection symbol may be part of a simplified connection diagram.

f) Minimum time required between disconnection and reclosure of the bank.

10.4 Marking of the Terminals

10.4.1 The marking of terminals of the capacitors of various configuration shall be:

Configuration of Correction	*Marking of Terminal*
a) Three-phase capacitors having three terminals only	No marking is necessary
b) Single-phase unit having two insulated terminals	No marking is necessary
c) Three-phase capacitors with electrically separate phases	A2, A1; B2, B1; C2, C1; corresponding to each separate phases
d) Two-phase, 3 wire capacitor	A2, B2, N corresponding to each phase terminals and neutral or common terminal, respectively
e) Two-phase, 4 wire capacitors	A2, B2 corresponding to each phase and A1, B1 corresponding to neutral terminal

10.5 The capacitor unit or bank may also be marked with the Standard Mark. Details for use of Standard Mark may be obtained from the Bureau of Indian Standards.

11 TEST REQUIREMENTS

11.1 General

The requirements specified in **11** to **27** lay down the requirements for capacitor units. The supporting insulators, switches, instrument transformers, fuses, etc, shall be in accordance with the relevant Indian Standard.

11.2 Test Conditions

Unless otherwice specified for a particular test or measurement, the temperature of the capacitor dielectric at the start of the test shall be in the range of +10°C to 45°C. It may be assumed that the dielectric temperature is the

same as the ambient temperature, provided that the capacitor has been left in an un-energized state at a constant ambient temperature for an adequate period.

When a correction has to be applied, the reference temperature to be used is 27 ± 2°C unless otherwise agreed to between the manufacturer and the purchaser.

The ac tests and measurements shall be carried out at a frequency of 50 Hz irrespective of the rated frequency of the capacitor, if not otherwise specified.

Capacitors having a rated frequency below 50 Hz shall be tested and measured at 50 Hz if not otherwise specified.

12 CLASSIFICATION OF TESTS

12.0 The tests are classified as:

a) Routine tests (*see* **12.1**),

b) Type tests (*see* **12.2**), and

c) Acceptance tests (*see* **12.3**).

12.1 Routine Tests

Routine tests shall have been carried out by the manufacturer on every capacitor before delivery. If the purchaser so requests, he shall be supplied with a certificate detailing the results of such tests.

12.1.1 The following shall constitute routine tests on capacitor units:

a) Visual examination (*see* **13**);

b) Sealing test (*see* **14**);

c) Measurements of capacitance and output (*see* **15**),

d) Insulation resistance between terminals and capacitor container (*see* **16**);

e) Capacitor loss tangent (tan δ) measurement (*see* **17**),

f) ac voltage test between terminals (*see* **18**);

g) ac voltage tests between terminals and container (*see* **19**); and

h) Test for discharge devices (*see* **20**).

12.1.2 The following shall constitute routine tests on capacitor banks:

a) Measurement of capacitance and output (*see* **15**); and

b) Insulation resistance between terminals and container (*see* **16**);

NOTE — Capacitor banks shall be made from capacitor units tested as per **12.1.1**

12.2 Type Tests

Type test are carried out in order to ascertain that, as regards design, size, material and construction, the capacitor complies with the specified characteristics and operation requirements detailed in this standard. Unless otherwise specified, every capacitor sample to which it is intended to apply the type test shall first have withstood satisfactorily the application of all the routine tests given in **12.1**.

The type tests shall have been carried out by the manufacturer, and the purchaser shall, on request, be supplied with a certificate detailing the results of such tests.

12.2.1 *Criteria of Approval*

One sample or more shall be submitted for testing together with relevant data. The testing authority shall issue a type test approval certificate if the capacitors are found to comply with requirements of test given in **12.2.2**.

12.2.2 The following shall constitute type tests on capacitor units:

a) Voltage test between terminals (*see* **18.2**);

b) Voltage test between terminals and container (*see* **19.2**);

c) Thermal stability test (*see* **21**);

d) Capacitor loss tangent (tan δ) measurements at elevated temperature (*see* **22**);

e) Self-healing test (*see* **23**);

f) Lightning impulse voltage test between terminals and container (*see* **24**);

g) Short circuit discharge test (*see* **25**);

h) Ageing test (*see* **26**); and

j) Destruction test (*see* **27**).

12.3 Acceptance Tests

The routine and/or type tests, or some of them, may be repeated by the manufacturer in connection with any contract by agreement with the purchaser. The kind of tests, the number of samples that may be subjected to such repeated tests and the acceptance criteria shall be subject to agreement between the manufacturer and the purchaser. Unless agreed otherwise, the recommended plan of sampling for acceptance tests given in Annex F shall be followed.

12.3.1 The following are recommended as acceptance tests on capacitor units:

a) Visual examination (*see* **13**);

b) Test for capacitance and output (*see* **15**);

c) Capacitor loss tangent (tan δ) measurement (*see* **17**);

d) Insulation resistance (*see* **16**);

e) ac voltage test between terminals (*see* **18**);

f) ac voltage tests between terminals and container (*see* **19**);

g) Test for discharge device (*see* **20**); and

h) Sealing test (*see* **14**).

12.3.2 The following are recommended as acceptance tests on capacitor banks:

a) Test for capacitance and output (*see* **15**), and

b) Insulation resistance (*see* **16**).

13 VISUAL EXAMINATION

The capacitor unit bank shall be manufactured in accordance with good engineering practice The visual examination shall be sufficient for checking compliance with workmanship, finish and marking (**10**).

14 SEALING TEST

After degreasing, unenergized capacitor units shall be stored in a position most likely to reveal leakage and heated throughout so that all parts of the container reach a temperature not lower than 20°C above the maximum value in Table 1 corresponding to the temperature symbol and shall be maintained at this temperature for 2 h.

No leakage shall occur.

It is recommended that a suitable indicator such as talcum powder be used to detect leakage.

NOTE — If the manufacturer certifies that capacitor contains no materials that are liquid at the sealing test temperature, than the test may be omitted as routine test

15 MEASUREMENTS OF CAPACITANCE AND OUTPUT

15.1 Capacitance

The capacitance shall be measured at the rated voltage and at the frequency chosen by the manufacturer. The method used shall not include errors due to harmonics or accessories external to the capacitor to be measured such as reactors and blocking circuits in the measuring circuit. The accuracy of the measuring method and correlation with the values measured at rated voltage and frequency shall be given. The capacitance measurement shall be carried out after the voltage test between terminals (*see* **18**).

Measurement at a voltage between 0·9 and 1·1 times the rated voltage and at a frequency between 0·8 and 1·2 times the rated frequency shall be performed on the capacitor used for the thermal stability test (*see* **21**), the ageing test (*see* 26) and the self-healing test (*see* **23**) before these tests and could be performed on other capacitors on request of the purchaser in agreement with the manufacturer. In polyphase units, the value of the line current with symmetrical supply voltage shall not differ by more than 5 percent from the highest value.

15.2 Output

A formula for calculation of the output of a three-phase capacitor from single-phase capacitance measurements is given in Annex B.

15.3 Tolerances

The capacitance and output shall not differ from the rated capacitance by more than:

— 5 to + 10 percent for units and banks up to 100 kvar

— 0 to + 10 percent for units and banks above 100 kvar

The capacitance value is that measured under the conditions of **15.1**

In three-phase units, the ratio of maximum to minimum value of the capacitance measured between any two line terminals shall not exceed 1·05.

16 INSULATION RESISTANCE BETWEEN TERMINALS AND CAPACITOR CONTAINER

Every capacitor shall be subjected to an insulation test between terminals and container except when one terminal of the capacitor is connected to the container. The test shall be made with a dc voltage not less than 500 V. The ripple content in the test voltage shall be not more than 10 percent. The insulation resistance so determined shall be not less than 50 megohms. In case of capacitors having three terminals brought out, the insulation resistance shall be determined between terminals (all connected together externally) and the container.

17 CAPACITOR LOSS TANGENT (TAN δ) MEASUREMENT

17.1 The dielectric loss angle (tan δ) shall be measured by means of Schering Bridge or other method capable of giving sufficient accurate results. The measurements shall be carried out within standard ambient temperature range (*see* **11.2**) and at 0·9 to 1·1 time the rated voltage, at standard rated frequency. In the case of three-phase delta connected capacitor bank, the measurements may be made in turn between terminals 1 and 2-3 connected together, 2 and 3-1 connected together and 3 and 1-2 connected together. The measurements of capacitor loss shall be carried out after the voltage test between terminals (*see* **18**).

The capacitor loss angle measurements shall be performed on the capacitor used for thermal stability test (*see* **21**) prior to this test and could be performed on other capacitors on request of the purchaser in agreement with the manufacturer.

NOTE — The tan δ value of certain types of dielectric is a function of the energization time before the measurement.

17.2 Loss Requirements

The value of tan δ measured in accordance with **17.1** shall not exceed the value agreed to between the manufacturer and the user. However, the value of tan δ shall not exceed the following:

a) Metallized polypropylene film with internal inductive coil and discharge resistor	0·002 5
b) Double metallized paper with plain polypropylene film impregnated with dielectric oil	0·001 0
c) Single metallized paper with plain polypropylene film impregnated with dielectric oil	0·002 0

18 ac VOLTAGE TEST BETWEEN TERMINALS

18.1 Routiue Test

Every capacitor shall be subjected to an ac test at $U_t = 1·75\ U_N$ for a minimum time of 2 sec.

18.1.1 The ac test shall be carried out with a substantially sinusoidal voltage at a frequency between 15 Hz and 100 Hz and preferably as near as possible to the rated frequency.

18.1.2 During the test no permanent breakdown or flashover shall occur. Self-healing breakdowns are permitted. Before and after the voltage test, the capacitance shall be measured. The change in capacitance shall be limited to 2 percent.

NOTES

1 For polyphase capacitors, the test voltages shall be adjusted as appropriate.

2 Operation of internal element fuses is permitted, provided the capacitance tolerances (*see* **15.3**) are still met and that not more than two fuses have operated per unit.

18.2 Type Test

Each capacitor shall be subjected to an ac test at $U_t = 1·75\ U_N$ for a duration of 10 sec. The ac test shall be carried out with a substantially sinusoidal voltage.

18.2.1 During the test no permanent breakdown or flashover shall occur. Self-healing breakdowns are permitted Before and after the voltage test, the capacitance and loss tangent delta shall be measured. The change in capacitance shall be limited to 2 percent and the increase in value of tan δ to 2×10^{-4} when measured at 27° ± 2°C.

NOTES

1 For polyphase capacitors, the test voltages shall be adjusted as appropriate

2 Operation of internal element fuses is permitted, provided the capacitance tolerances (*see* **15.3**) are *still met*.

19 ac VOLTAGE TESTS BETWEEN TERMINAL AND CONTAINER

19.1 Routine Tests

Units having all terminals insulated from the container shall be subjected to a voltage applied between the terminals (joined together) and the container, of 3 kV for 10 sec or 3·6 kV for 2 sec. During the test, neither puncture nor flashover shall occur.

19.1.1 The test shall be performed, even if, in service, one of the terminals is intended to be connected to the container.

19.1.2 Three-phase units having separate phase capacitances may be tested with respect to the container with all the terminals joined together.

19.1.3 Units having one terminal permanently connected to the container shall not be subjected to this test.

19.1.4 When the unit container consists of insulating material this test shall be omitted.

19.1.5 If a capacitor has separate phases or sections, a test of the insulation between phases or sections should be made, at the same voltage value as for the terminals to container test

19.2 Type Test

Units having all terminals insulated from the container shall be subjected to a test according to **19.1** with a voltage of 3 kV for a duration of 1 min

19.2.1 The test on units having one terminal permanently connected to the container shall be limited to the bushing(s) and, container (without elements) If the capacitor container is of insulating material, the test voltage shall be applied between the terminals and metal foil wrapped closely round the surface of the container excluding the surface carrying capacitor terminals

19.2.2 The test shall be made under dry conditions for indoor units and with artificial rain [*see* IS 2071 (Part 2) 1976] for units to be used outdoors

19.2.3 During the test, neither puncture nor flashover shall occur

NOTE — Units intended for outdoor installation may be subjected to a dry test only The manufacturer shall in such a case supply a separate type test report showing that the bushing will withstand the wet test voltage for 1 min

20 TEST FOR DISCHARGE DEVICES

20.1 Internal Discharge Device

The resistance of the internal discharge device, if any, shall be checked either by a resistance measurement (*see* also **20 2**) or by measuring the self-discharging rate (*see* **7.1**) The choice of the method is left to the manufacturer

The test shall be made after the voltage tests (*see* **18**)

20.2 Efficacy of Discharge Device

In general the method of test employed shall depend upon the nature of the discharge device fitted to the capacitor These devices fall in two main groups, namely, (a) those which consist mainly or entirely of a high resistance, and (b) those that possess a high inductive reactance which may be of moderate or low resistance only

20.2.1 *Procedure*

The resistance value of the first group of discharge devices can be measured by a dc test and the discharge time calculated from that measured resistance and the known capacitance of the capacitor (or capacitor group) to which it is connected.

If C is the capacitance in microfarads of the capacitor shunting the resistance R in ohms, the time t to discharge to 50 volts can be calculated from the formula

$$t = 2.3 \times 10^{-6} \, CR \, (\log_{10} U_N - 1.55) \text{ sec}$$

where

U_N is the rated rms voltage of the capacitor in volts Usually this test should be made with a dc voltage equal to 1.4 times the rms rated voltage of the capacitor since the charge in the capacitor may be at this voltage if the switch opens at or near the peak of the ac voltage wave Measurement at this voltage is necessary because any of the resistance discharge devices have a non-linear characteristic and in consequence have a different resistance value at high voltages from that which they show at low voltages

In the case of the second type of discharge device the application of high dc voltage might cause damage to or destruction of the discharge device owing to its relatively low ohmic resistance so that some other method of test, such as an actual measurement of the discharge time should be employed

21 THERMAL STABILITY TEST

21.1 General

This test provides the following information about the capacitors subjected to it

a) It determines the thermal stability of the capacitor under overload conditions (*see* **6**)

b) It conditions the capacitor to enable a reproducible tangent loss measurement to be made

21.2 Measuring Procedure

21 2.1 The capacitor unit subjected to the test shall be placed between two other units of the same rating which shall be energized at the same voltage as the test capacitor Alternatively, two dummy capacitors each containing resistors may be used The dissipation in the resistors shall be adjusted to a value such that the case temperatures of the dummy capacitors near the top opposing faces are equal to or greater than those of the test capacitor The

separation between the units shall be equal to, or less than, the normal spacing. The assembly shall be placed in still air in a heated enclosure in the most unfavourable thermal position according to the manufacturer's instructions for mounting on site. The ambient air temperature shall be maintained at the appropriate temperature shown in Table 3.

It shall be checked by means of a thermometer having a thermal time constant of approximately 1 h.

The ambient air thermometer should be shielded so that it is subjected to the minimum possible thermal radiation from the three energized samples.

21.2.2 After all parts of the capacitor have attained the temperature of the ambient air, the capacitor shall be subjected for a period of at least 48 h to an ac voltage of substantially sinusoidal form. The magnitude of the voltage shall be kept constant throughout the test. Its value is computed from the measured capacitance (*see* **15.1**) to give a calculated output of the capacitor equal to 1.44 times its rated output. The voltage to be applied for obtaining the output should be calculated from the following equation:

$$U_t = 1.2\,U_n \sqrt{\frac{C_n}{C_t}}$$

where

C_n – capacitance corresponding to the rated output, and

C_t – measured capacitance of the capacitor to be tested.

During the last 10 h the temperature of the container near the top shall be measured at least six times at an interval of approximately 2 h. Throughout this period of 10 h, after 38, 40, 42, 44, 46 and 48 hours the temperature rise shall not increase by more than 2 C between the readings. Should a greater change be observed, the test may be continued until the above requirement is satisfied for four consecutive measurments during a 10 h period. In case the thermal stability condition is not reached in 72 h the testing shall be stopped and the capacitor shall be declared to have failed in this test.

At the end of the stability test the difference between the measured temperature of the case and cooling air temperature shall be recorded.

Before and after the test the capacitance (*see* **15**) shall be measured (*see* **15.1**) within the standard temperature range for testing and two measurements shall be corrected to the same dielectric temperature.

Change of capacitance greater than 2 percent shall not be allowed from these measurements.

A measurement of loss angle (*see* **17**) shall be made before and after the thermal stability test at a temperature of 27 ± 2°C. The measurement shall be carried out at rated voltage and rated frequency of the capacitor unit.

The value of the second measurement of loss angle shall be not greater than that of the first by more than $2 \cdot 10^{-4}$.

When interpreting the results of the measurements, two factors shall be taken into account.

a) The reproducibility of the measurements,

b) The fact that internal change in dielectric may cause a small change of capacitance without puncture of any element of the capacitor or blowing of an internal fuse having occurred.

NOTES

1 When checking whether the capacitor losses or temperature conditions are satisfied, fluctuations of voltage, frequency and cooling air temperature during the test shall be taken into account. For this reason, it is advisable to plot these parameters and the tangent of the loss angle at the temperature rise as a function of time. The measurement being carried out at rated voltage and rated frequency.

2 Three phase capacitor banks or units shall require three phase power supply and single-phase units shall be tested with single phase transformers while carrying out thermal stability test.

22 CAPACITOR LOSS TANGENT (TAN δ) MEASUREMENTS AT ELEVATED TEMPERATURE

22.1 Measuring Procedure

The capacitor losses (tan δ) shall be measured at the end of the thermal stability test (*see* **21**). The measuring voltage shall be that of the thermal stability test.

Table 3 Ambient Air Temperature (°C)

(*Clause* 21.2.1)

Symbol	Ambient Air Temperature
A	40
B	45
C	50
D	55
Temperature tolerance ± 2° C	

22.2 Requirements

The value of tan δ measured in accordance with **21.1** shall not exceed the value given in **17.2** or the value agreed upon between the manufacturer and the purchaser for the temperature and the voltage of the test.

23 SELF-HEALING TEST

The capacitors covered by this standard shall meet the requirements of **6** IS 13341 : 1992.

24 LIGHTNING IMPULSE VOLTAGE TEST BETWEEN TERMINALS AND CONTAINER

24.1 Only units having all terminals insulated from the container and intended for installation exposed to overvoltages of atmospheric origin shall be subjected to this test.

24.2 Unless otherwise agreed to between the manufacturer and the purchaser, the impulse test shall be performed with a wave of 1 2 to 5/50 μs having a crest value of 15 kv [*see* IS 2071 (Part 2) : 1976] 3 impulses of positive polarity followed by 3 impulses of negative polarity shall be applied between terminals joined together and the container.

24.3 After the change of polarity it is permissible to apply some impulses of lower amplitude before the application of the test impulses.

24.4 The absence of failure during the test shall be verified by a cathode ray oscillograph, which is used to record the voltage and to check the wave shape

24.5 If the capacitor container is of insulating material the test voltage shall be applied between the terminals and a metal foil wrapped closely round the surface of the container. The metal foil of suitable thickness shall be wrapped upto top edge of the capacitor excluding the terminals.

NOTE — Partial discharge in the insulation to the container may be indicated by the modification of the wave shapes between the different impulse.

25 SHORT CIRCUIT DISCHARGE TEST

25.1 The units shall be charged by means of dc and then discharged through a gap situated as close as possible to the capacitor. They shall be subjected to five such discharges within 10 min.

25.1.1 The test voltage shall be equal to 2 U_n. Within five minutes after this test, the unit shall be subjected to a voltage test between terminals (*see* **18.1**).

25.1.2 The capacitance shall be measured before the discharge test and after the voltage test. The measurements shall not differ by an amount corresponding either to breakdown of an element or to blowing of an internal fuse or by more than 2 percent.

25.2 For polyphase units the test shall be carried out between two terminals only. In the case of three-phase delta connection, two terminals shall be short-circuited. For star connection, no terminals shall be short-circuited.

25.2.1 The test voltage shall be adjusted to have voltage 2 times rated element voltage. If the first peak of the test current exceeds the value of 200 IN (rms) it may be kept at this limit by means of an external coil.

26 AGEING TEST

The self-healing capacitors shall meet the requirements of **5** of IS 13341 : 1992.

27 DESTRUCTION TEST

The self-healing capacitors shall meet the requirements of **7** of IS 13341 . 1992.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No	*Title*
1885 (Part 42) : 1986	Electrotechnical vocabulary: Part 42 Power capacitors (*second revision*)
2071 (Part 2) : 1976	Methods of high voltage testing: Part 2 Test procedures (*first revision*)
3723	Capacitors for radio interference suppression (Issued in parts)
4905 : 1968	Methods for random sampling
9224	Low voltage fuses (Issued in parts)
12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
12672 : 1989	Internal fuses and internal overpressure disconnectors for shunt capacitors
13585 (Part 1) : 1993	*Shunt capacitors for ac* power systems having a rated voltage up to and including 650 V Part 1 Specification
13341 : 1992	Requirements for ageing test, self-healing test and destruction test on shunt capacitors of the self-healing type for ac power systems having a rated voltage up to and including 650 V

ANNEX B

[*Clauses* 4.1 (a), 10.1 (d) *and* 15.2]

FORMULAE FOR CAPACITORS AND INSTALLATIONS

B-1 COMPUTATION OF THE OUTPUT OF THREE-PHASE CAPACITORS FROM THREE SINGLE-PHASE CAPACITANCE MEASUREMENTS

B-1.1 The capacitances measured between any two line terminals of three-phase capacitor of either delta or star connection are denoted as Ca, Cb and Cc. If the symmetry requirements laid down in **15.1** are fulfilled, the output Q of the capacitor can be computed with sufficient accuracy from the formula

$$Q = \frac{2}{3} (Ca + Cb + Cc) \omega U_N^2 \times 10^{-9}$$

where

Ca, Cb and Cc are expressed in μF,

U_N is expressed in V, and

Q is expressed in kvar.

B-1.2 Computation of Output from Voltage Current Method

An alternating voltage shall be applied and the current taken by the capacitor measured. The kvar output shall be calculated from voltages and current readings using the formulae given in Table 4.

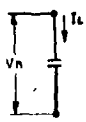
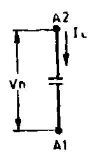
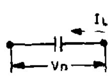
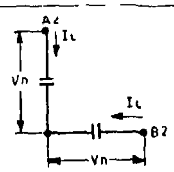
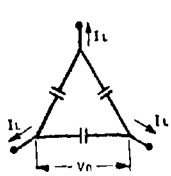
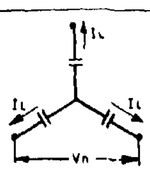
Where the capacitor is arranged for polyphase connection, the mean value of the rms line currents (ignoring neutral current, if any) shall be used for calculating the kvar output.

When using this method, the supply frequency should be checked and the supply voltage should be substantially free from harmonics.

If the test frequency differs from the rated frequency, the kvar output should be calculated from the test results, bearing in mind that

Table 4 Reactive Outputs for Different Connections

(*Clause* B-1.2)

Diagram	Type of Connection	Capacitance Measured Between	Formulae for Calculating kvar: From Current Reading Method 1	Formulae for Calculating kvar: From Capacitance Reading of Col 3, Method 2	kvar Factor
(1)	(2)	(3)	(4)	(5)	(6)
	Single phase	Line terminals	$\frac{V_n I_L}{1\,000}$	$\frac{2\pi f C V_n^2}{10^9}$	1
	Two phase four wire	A_1 and A_2 also B_1 and B_2	$\frac{2V_n I_L}{1\,000}$	$\frac{4\pi f C V_n^2}{10^9}$	2
	Two-phase three wire	A_2 and N B_2 and N	$\frac{2V_n I_L}{1\,000}$	$\frac{4\pi f C V_n^2}{10^9}$	2
	Three phase delta connected	Three pairs of line terminals	$\frac{\sqrt{3} V_n I_L}{1\,000}$	$\frac{4\pi f C V_n^2}{10^9}$	$\sqrt{3}$
	Three-phase star connected	Three pairs of line terminals	$\frac{\sqrt{3} V_n I_L}{1\,000}$	$\frac{4\pi f C V_n^2}{10^9}$	$\sqrt{3}$
		Three line terminals separately and neutral if brought out	$\frac{2\pi f C V_n^2}{10^9}$		

where

f – Rated frequency,

V_n – Rated voltage,

C – Capacitance (microfarads), and

I_L – Line current (amperes) under normal working conditions.

output is directly proportional to the frequency at constant voltage. If the applied voltage differs from the rated voltage, then the kvar output shall be calculated from the test results bearing in mind that output is proportional to the square of the applied voltage at constant frequency.

B-2 RESONANCE FREQUENCY

A capacitor will be in resonance with a harmonic, in accordance with the following equation in which n is an integer.

$$n = \sqrt{\frac{S}{Q}}$$

where

- S = short circuit power (MVA) where the capacitor is to be installed;
- n = harmonic number, that is the ratio between the resonant harmonic (Hz) and the network frequency (Hz), and
- Q = is expressed, in Mvar (*see* **8-1.1**).

B-3 VOLTAGE RISE

Connection of a shunt capacitor will cause the steady-state voltage rise given by the following expression:

$$\frac{\Delta U}{U} \approx \frac{Q}{S}$$

where

- ΔU = voltage rise,
- U = voltage before connection of the capacitor,
- S = the short-circuit power (MVA) where the capacitor is to be installed, and
- Q = expressed in Mvar.

B-4 INRUSH TRANSIENT CURRENT

B-4.1 Switching of Single Capacitor

$$\hat{I}_s \approx I_N \sqrt{\frac{2S}{Q}}$$

where

- $\hat{I}_s$ = crest of inrush capacitor current,
- I_N = rated capacitor current (rms),
- S = the short-circuit power (MVA) where the capacitor is to be installed, and
- Q = expressed in Mvar.

B-4.2 Switching of Capacitor in Parallel with Energized Capacitor (s)

$$\hat{I}_s = \frac{U\sqrt{2}}{\sqrt{X_C X_L}}$$

$$f_s = f_n \sqrt{\frac{X_C}{X_L}}$$

where

- $\hat{I}_s$ = crest of inrush capacitor current,
- U = phase-to-earth voltage (V),
- X_C = series-connected capacitive reactances per phase (Ω),
- X_L = inductive reactance per phase between the banks (Ω),
- f_s = frequency of the inrush current (Hz), and
- f_n = rated frequency (Hz).

B-4.3 Discharge Resistance in Single-phase Unit or in One Phase of Polyphase Units

$$R = \frac{t}{k\ C \cdot \log_e \left(\frac{U_N \sqrt{2}}{U_R} \right)}$$

where

- t = time for discharge from $U_N \sqrt{2}$ to U_R(s),
- R = equals discharge resistance [MΩ],
- C = rated capacitance (µF) per phase,
- U_N = rated voltage of unit (V),
- U_R = permissible residual voltage (V) (*see* **7.1** for limits of t and U_R),
- k = coefficient depending on both resistance and capacitor unit connections,

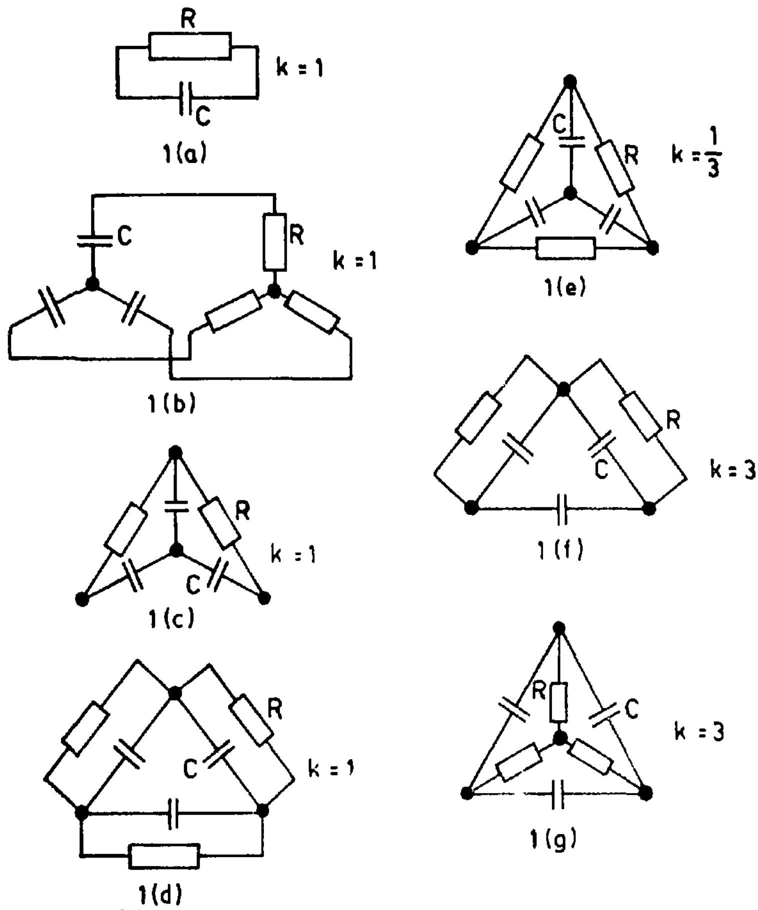


FIG. 1 EXAMPLES OF CAPACITOR UNITS AND VALUE OF COEFFICIENT 'k'

ANNEX C

(*Clause* 6.2.1)

EFFECTS OF HARMONICS

C-1 EFFECT OF HARMONICS

C-1.1 The reactance of a capacitor is inversely proportional to the frequency. Hence, if the applied voltage includes components having frequencies higher than the fundamental frequency, the current will be greater than that would be produced by the same voltage at the fundamental frequency.

C-1.2 As a result of this a comparatively small component of one of the higher harmonics can produce a current component comparable in magnitude to the normal capacitor current when fed from a pure sinusoidal supply and so cause an appreciable increase in the total capacitor current and corresponding increase in the kvar loading.

C-1.3 The actual current taken by a capacitor when higher frequency voltage components are present is the square root of the sum of the squares of the various current components including the fundamental.

C-1.4 In practice the higher frequency components are almost invariably the higher odd number harmonics of the fundamental supply frequency, such as the third, fifth, seventh, etc.

C-1.5 If the various harmonic voltages h_3, h_5, h_7, etc, are expressed as a percentage of the fundamental voltage, the rms value of the resultant voltage wave is given by the following:

$$V = 0.01\, V_1 \sqrt{(100^2 + h_3^2 + h_5^2 + h_7^2, \text{etc})}$$

The total capacitor current is given by the following expression:

$$I = 0.01\, I_1 \sqrt{(100^2 + 9h_3^2 + 25h_5^2 + 49h_7^2, \text{etc})}$$

where

V = rms circuit voltage,

V_1 = rms value of voltage at the fundamental frequency;

I = rms capacitor current;

I_1 = rms value of capacitor current due to V_1, and

h_3, h_5, h_7, etc, are the rms values of the third, fifth, seventh, etc, harmonics expressed as a percentage of V_1.

The percentage increase in reactive output due to the existence of harmonics voltage is given to an adequate approximation by

$$\Delta \text{kvar} = 0.01\ (\,3h_3^2 + 5h_5^2 + 7h_7^2 +, \text{etc}\,)$$

NOTE — It should be noted that the peak voltage of the wave may amount to the sum of the fundamental and all the individual harmonic peak voltages.

ANNEX D

(*Clause* 8.1)

GUIDE FOR INSTALLATION AND OPERATION

D-1 GENERAL

D-1.1 Unlike most electrical apparatus, shunt capcitors, whenever energized, operate continuously at full load, or at loads that deviate from this value only as a result of voltage and frequency variations.

Overstressing and overheating shorten the life of a capacitor, and therefore, the operating conditions (that is temperature, voltage and current) should be strictly controlled.

It should be noted that the introduction of concentrated capacitance in a system may produce unsatisfactory operating conditions (for exmple, amplification of harmonics, self-excitation of machines, overvoltages due to switching, unsatisfactory working of audio-frequency remote-control apparatus, etc).

Because of the different types of capacitor and the many factors involved, it is not possible to cover, by simple rules, installation and

operation in all possible cases. The following information is given with regard to the more important points to be considered.

In addition, the instructions of the manufacturer and the power supply authorities must be followed, especially those concerning the switching of capacitors when the net work is under light load conditions.

D-2 CHOICE OF THE RATED VOLTAGE

D-2.1 The rated voltage of the capacitor shall be equal to the service voltage of the network to which the capacitor is to be connected, account being taken of the influence of the presence of the capacitor itself.

In certain networks, a considerable difference may exist between the service and rated voltage of the network, details of which should be furnished by the purchaser, so that due allowance may be made by the manufacturer.

This is of importance for capacitors, since their performance and life may be adversely affected by an undue increase of the voltage across the capacitor dielectric.

Where circuit elements are inserted in series with the capacitor to reduce the effects of harmonics, etc, the resultant increase in the voltage at the capacitor terminals above the service voltage of the network necessitates a corresponding increase in the rated voltage of the capacitor.

If no information to the contrary is available the service voltage shall be assumed as equal to the rated (or declared) voltage of the network.

When determining the voltage to be expected on the capacitor terminals, the following considerations shall be taken into account:

a) Shunt connected capacitors may cause a voltage rise from the source to the point where they are located (*see* Annex B); this voltage rise may be greater due to the presence of harmonics. Capacitors are therefore, liable to operate at a higher voltage than that measured before connecting the capacitors.

b) The voltage on the capacitor terminals may be particularly high at times of light load conditions (*see* Annex B); in such cases, some or all of the capacitors should be switched out of circuit in order to prevent over stressing of the capacitors and undue voltage increase in the network.

Only in case of emergency should capacitors be operated at maximum permissible voltage and maximum ambient temperature simultaneously, and that to for short period of time.

NOTES

1 An excessive safety margin in the choice of the rated voltage U_N should be avoided, because this would result in decrease of output when compared with the rated output.

2 *See* **6.1** concerning maximum permissible votlage.

D-3 OPERATING TEMPERATURE

D-3.1 General

Attention should be paid to the operating temperature of the capacitor, because this has a great influence on its life. In this respect, temperature of the hot spot is a determining factor, but it is difficult to measure this temperature in practical operation.

Temperature in excess of ν *Max* accelerates electrochemical degradation of the dielectric. Temperature below ν *Min* or very rapid changes from hot to cold may initiate partial discharge degradation in the dielectric.

D-3.2 Installation

Capacitors shall be so placed that there is adequate dissipation by convection and radiation of the heat produced by the capacitor losses.

The ventilation of the operating room and the arrangement of the capacitor units shall provide good air circulation around each unit. This is of importance for units mounted in rows one above the other.

The temperature of capacitors subjected to radiation from the sun or from any high-temperature surface will be increased.

Depending on the cooling air temperature the intensity of the cooling and the intensity and duration of the radiation, it may be necessary to opt for one of the following remedies:

a) To protect the capacitors from radiation;

b) To choose a capacitor designed for a higher ambient air temperature (for example, category -5/B, instead of -5/A, which is otherwise suitably designed); and

c) To employ capacitors with rated voltage higher than that laid down in **D-2.**

Capacitors installed at high altitudes (more than 1 000 m) will be subjected to decreased heat dissipation, which shall be considered when determining the power of the units [*see* **D-4** (e)]

D-3.3 High Ambient Air Temperature

Symbol C capacitors are suitable for the majority of applications under tropical conditions In some locations however, the ambient temperature may be such that symbol D capacitor is required The latter may also be needed for those cases where the capacitors are frequently subjected to the radiation of the sun for several hours (for example, in desert territories), even though the ambient temperature is not excessive (*see* **D-3.2**)

In exceptional cases, the ambient temperature may be higher than 55 C maximum, or 45°C daily average Where it is impossible to increase the cooling conditions, capacitors of special design or with a higher rated voltage shall be used

D-3.4 Evaluation of Losses

If losses are to be evaluated, all accessories producing losses, such as external fuses, reactors etc shall be included in the calculation of total bank losses

D-4 SPECIAL SERVICE CONDITIONS

D-4.1 Apart from the conditions prevailing at both limits of the temperature category (*see* **D-3.1**), the most important conditions which the manufacturer shall be informed about are the following

a) *High Relative Humidity* — It may be necessary to use insulators of special design Attention is drawn to the possibility of external fuses being shunted by a deposit of moisture on their surfaces

b) *Rapid Mould Growth* - Mould growth does not develop on metals, ceramic materials and some kinds of paints and lacquers For other materials, mould growth may develop on humid places especially where dust, etc, may settle The use of fungicidal products may improve the behaviour of these materials but such products do not retain their poisoning property for more than a certain period

c) *Corrosive Atmosphere* — Corrosive atmosphere is found in industrial and coastal areas It should be noted that in climates of higher temperature the effects of such atmospheres may be more severe than in temperate climates Highly corrosive atmosphere may be present even in indoor application

d) *Pollution* —When capacitors are mounted in a location with a high degree of pollution, special precautions shall be taken

e) *Altitude Exceeding 1 000 m* — Capacitors used at altitudes exceeding 1 000 m are subject to special conditions. The choice of the type should be made by agreement between the purchaser and the manufacturer

D-5 OVERVOLTAGES

D-5.1 Overvoltage factors are specified in **6.1.** With the manufacturer's agreement, the overvoltage factor may be increased if the estimated number of overvoltages is lower, or if the temperature conditions are less severe These power frequency overvoltage limits are valid, provided that transient overvoltages are not superposed on them The peak voltage shall not exceed 1 41 times the given rms value.

Capacitors that are liable to be subjected to high overvoltages due to lightning should be adequately protected If lightning arresters are used, they should be located, as near as possible to the capacitors

Special arresters may be required to take care of the discharge current from the capacitor, especially from large banks

When a capacitor is permanently connected to a motor difficulties may arise after disconnecting the motor from the supply The motor, while still revolving may act as a generator by self-excitation and may give rise to voltages considerably in excess of the system voltage This, however can usually be prevented by ensuring that the capacitor current is less than the magnetizing current of the motor, a value of about 90 percent is suggested As a precaution live parts of a motor to which a capacitor is permanently connected should not be touched before the motor stops

NOTES

1 The maintained voltage due to self excitation after the machine is switched off is particularly dangerous for induction generators and for motors with a braking system intended to be operated by loss of voltage (for example, lift motors)

2 In the case where the motor stops when braked heavily while stopping after having been disconnected from the supply the compensation may exceed 90 percent

D-5.2 When a capacitor is connected to a motor associated with a star-delta starter the arrangement should be such that no overvoltage can occur during the operation of the starter

D-6 OVERLOAD CURRENTS

D-6.1 Capacitors should never be operated with currents exceeding the maximum value specified in **6.2**

Overload currents may be caused either by excessive voltage at the fundamental frequency or by harmonics, or both The chief sources of harmonics are rectifiers and saturated transformer cores

If the voltage rise at times of light load is increased by capacitors, the saturation of transformer cores may be considerable In this case, harmonics of abnormal magnitude are produced, one of which may be amplified by resonance between the transformer and the capacitor

This is a further reason for recommending the disconnection of capacitors at times of light load, as referred to in **D-2.1** (a)

If the capacitor current exceeds the maximum value specified in **6.2.1**, while the voltage is within the permissible limit of 1 10 U_N, as specified in **6.1.1** the predominant harmonic should be determined in order to find the best remedy

The following remedies should be considered

a) Moving some or all of the capacitors to other parts of the system,

b) Connection of a reactor in series with the capacitor, to lower the resonant frequency of the circuit to a value below that of the disturbing harmonic, and

c) increase of the capacitance value when the capacitor is connected close to rectifiers

The voltage waveform and the network characteristics should be determined before and after installing the capacitor, when sources of harmonics such as large rectifiers are present, special care should be taken

Transient overcurrents of high amplitude and frequency may occur when capacitors are switched into circuit Such transient effects are to be expected when a section of a capacitor bank is switched in parallel with other sections that are already energized (*see* Annex B)

It may be necessary to reduce these transient overcurrents to acceptable values in relation to the capacitor and to the equipment by switching on the capacitors through a resistor (resistance switching), or by the insertion of reactors in the supply circuit to each section of the bank

If the capacitors are provided with fuses (internal or external), the peak value of the overcurrents due to switching operations shall be limited to a maximum of 100 I_N (rms value)

D-7 SWITCHING AND PROTECTIVE DEVICES AND CONNECTIONS

D-7.1 The switching and protective devices and the connections shall be designed to carry continuously a current of 1 3 times the current that would be obtained with a sinusoidal voltage of an rms value equal to the rated voltage at the rated frequency As the capacitor may have a capacitance equal to 1 1 times the value corresponding to its rated output, this current may have a maximum value of 1 3 × 1 10 times the rated current

Moreover, harmonic components, if present, may have a greater heating effect than the corresponding fundamental component, due to skin effect

The switching and protective devices and the connections shall be capable of withstanding the electro-dynamic and thermal stresses caused by the transient overcurrents of high amplitude and frequency that may occur when switching on

Such transients are to be expected when a capacitor (unit or bank) is switched in parallel with other capacitor(s) that are already energized

When consideration of the electro dynamic and thermal stresses would lead to excessive dimensions special precautions such as those mentioned in **D-6** for the purpose of protection against overcurrents, should be taken.

NOTES

1 Fuses in particular should be chosen with adequate thermal capacity (*see* IS 9224 1979 and IS 12672 1989)

2 In certain cases, for example when the capacitors are automatically controlled repeated switching operations may occur at relatively short intervals of time Switchgear and fuses must be selected to withstand these conditions

3 Breakers connected to the same busbar may be subjected to special stress in the event of switching on a short circuit

4 Breakers for switching off parallel banks shall be able to withstand the inrush current (amplitude and frequency) resulting when one bank is connected to a busbar to which other bank(s) are already connected

It is recommended that capacitors be protected against overcurrent by means of suitable overcurrent relays, which are adjusted to operate the circuit-breakers when the current exceeds the permissible limit specified in **6.2** Fuses do not generally provide suitable overcurrent protection

NOTE — Depending on the design of the capacitors, their capacitance will vary more or less with temperature

Attention should be paid to the fact that the capacitance may change rapidly after the energization of cold capacitors

This may cause needless functioning of the protective equipment

If iron-cored reactors are used, attention should be paid to possible saturation and overheating of the core by harmonics

D-7.2 Any bad contacts in capacitor circuits may give rise to arcing, causing high-frequency oscillations that may overheat and overstress the capacitors

Regular inspection of all capacitor equipment contacts is, therefore, recommended.

D-8 CHOICE OF CREEPAGE DISTANCE — *(Under consideration)*

D-9 CAPACITORS CONNECTED TO SYSTEMS WITH AUDIO FREQUENCY REMOTE CONTROL

D-9.1 The impedance of capacitors at audio-frequency is very low When they are connected to systems having audio-frequency remote-control, overloading of the remote control transmitter and unsatisfactory working may, therefore, result

There are various methods of avoiding these deficiencies, the choice of the best method should be made by agreement between all parties concerned.

ANNEX E

(*Clause* 9)

INFORMATION TO BE GIVEN WITH ENQUIRY OR ORDER

E-1 The following information is recommended to be given at the stage of enquiry or order of the shunt power capacitors

1 Output required in kvar/Mvar

2 Rated voltage

3 Rated frequency

4 Number of phases

5 State whether any abnormal voltage rises are expected If so, state highest voltage expected

6 Upper limit of temperature category

7 Proposed location of capacitor indoors or outdoors

8 Altitude above sea level of capacitor location, if above the limit specified in **4.1**

9 Nature of supply circuit, for example, whether the capacitor is to be connected

   a) to a local substation (if so state kVA rating of transformers, etc), or

   b) to a local underground network, or

   c) to overhead lines

10 If capacitor is to be connected directly to overhead lines

   a) are thunder storms prevalent in the locality ?

   b) are lightning arresters or surge diverters fitted to the lines ?

11 Details of switchgear or automatic controlgear to be used with the capacitor.

12 If capacitor is to be connected directly to the terminals of a motor, state motor rating, speed, type, manufacturer and serial number

13 Any special requirement that may affect the design or operation of the capacitor

14 Whether the unit capacitor is to be used on line directly or assembled for forming capacitor bank

ANNEX F

(*Clause* 12.3)

SAMPLING PLAN FOR SHUNT CAPACITORS FOR POWER SYSTEMS

F-1 SCALE OF SAMPLING

F-1.1 Lot

All the shunt capacitors of the same rating manufactured from the same material under similar conditions of production shall be grouped together to constitute a lot.

F-1.2 The number of shunt capacitors to be selected from each lot shall depend upon the size of the lot and shall be in accordance with col 1 and 2 of Table 5.

F-1.2.1 These shunt capacitors shall be selected from the lot at random. In order to ensure the randomness of selection, procedure given in IS 4905 : 1968 may be followed.

F-2 NUMBER OF TESTS AND CRITERIA FOR CONFORMITY

F-2.1 The shunt capacitors selected at random according to col 1 and 2 of Table 5 shall be subjected to each of the acceptance tests. A shunt capacitor failing to satisfy the requirements of any of these tests shall be termed as defective. The lot shall be considered as conforming to these requirements if the number of defectives found in the sample is less than or equal to the corresponding permissible number given in col 3 of Table 5 otherwise the lot shall be rejected.

Table 5 Sample Size and Permissible Number of Defectives

(*Clauses* F-1.2 *and* F-2.1)

Lot Size	Sample Size	Permissible No. of Defectives
(1)	(2)	(3)
Up to 100	8	0
101 to 300	13	0
301 to 500	20	1
501 to 1 000	32	2
1 001 and above	50	3

(*Continued from second cover*)

The shunt capacitors are extensively recommended for improvement of power factor in the electricity distribution lines. Therefore, the capacitors/capacitor banks play a vital role in the economies of energy consumption.

IS 2834 : 1964 covered safety and performance of shunt capacitors. Its revised version IS 2834 : 1986 covered non-self-healing and self-healing type shunt capacitors for power system irrespective of its voltage ratings. It has now been found convenient to prepare separate standards on shunt capacitors and the special type test as follows:

a) Shunt capacitors of non-self-healing type for ac power systems having rated voltage up to 650 V.

b) Shunt capacitors of self-healing type for ac power systems having rated voltage up to 650 V.

c) Shunt capacitors for ac power systems having rated voltage above 650 V (*Under preparation*).

d) Requirements for endurance testing of shunt capacitors for ac power system having rated voltage above 650 V.

This standard is based on IEC Pub 831-1 (1988) 'Shunt capacitors of the self-healing type for ac power systems having a rated voltage up to and including 660 V', issued by the International Electrotechnical Commission.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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